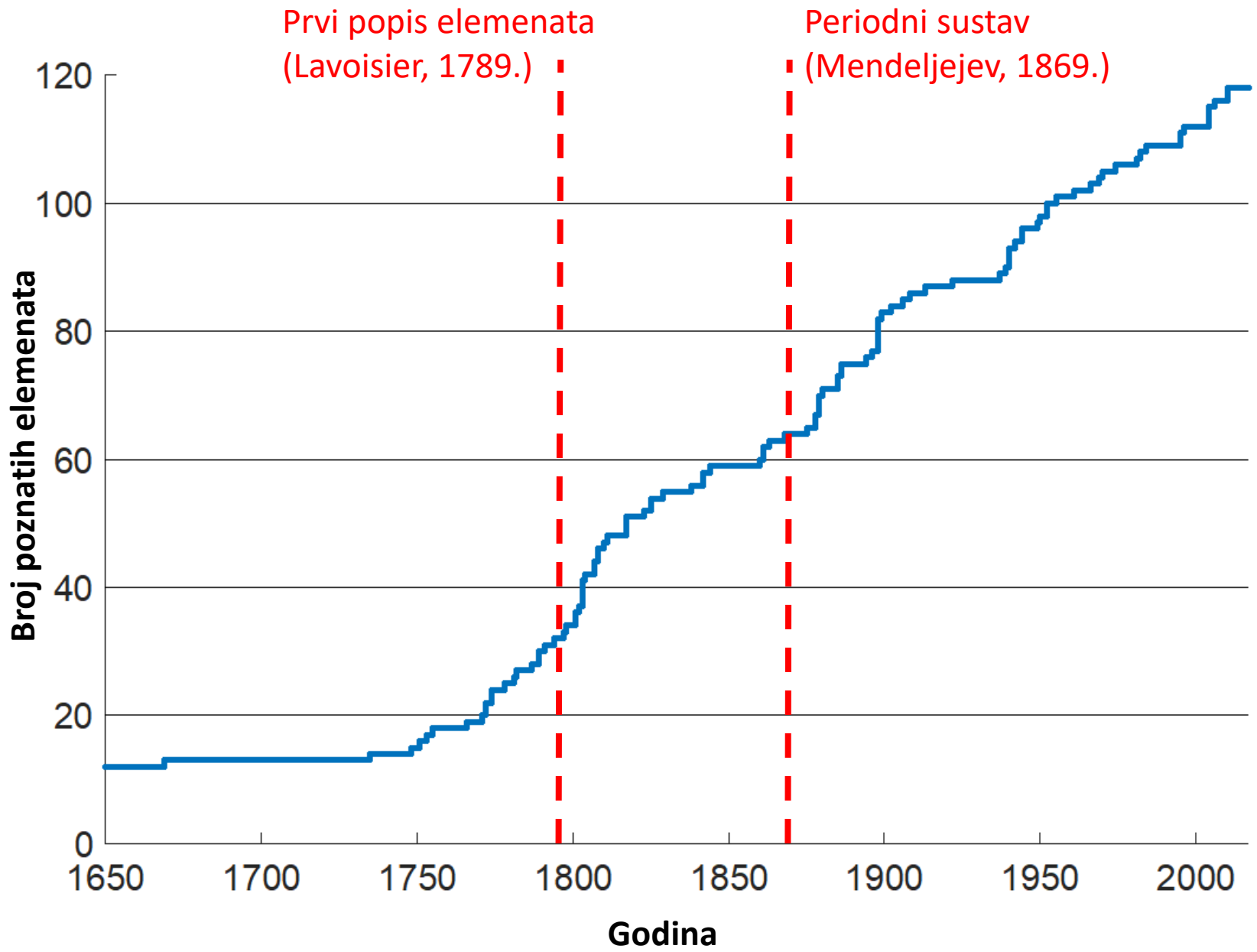
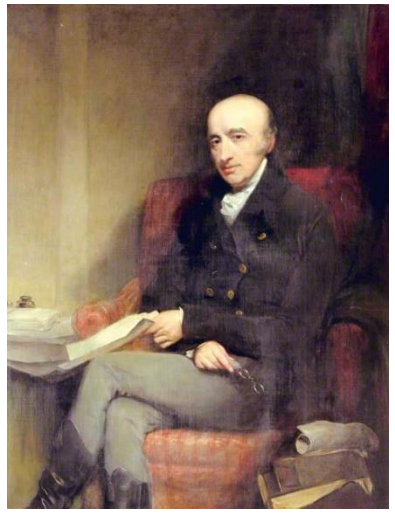
12.
klasifikacija elemenata i periodičnost


Prvi popis elemenata
(Lavoisier, 1789.)
Periodni sustav
(Mendeljejev, 1869.)
Broj poznatih elemenata
120
100
80
60
40
20
0
1650
1700
1750
1800
1850
1900
1950
2000
Godina

Spektralna analiza



William Hyde **Wollaston**
(1766.–1828.)

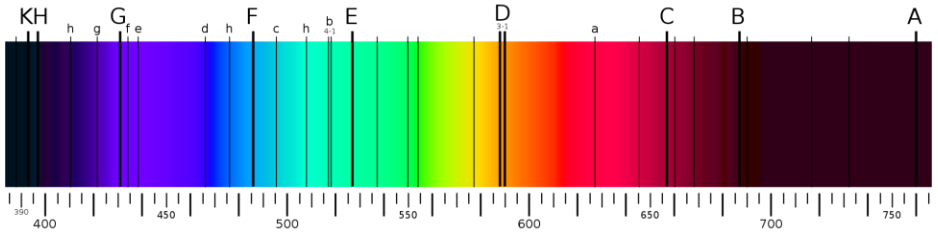
1802. (Wollaston) – linije u Sunčevu spektru (granice među bojama)

1814. (Fraunhoffer) – difrakcijska rešetka – mnoštvo linija u sunčevom spektru (Fraunhofferove linije)

1820-ih (Talbot i John Herschel) – soli različitih metala različito bojaju plamen

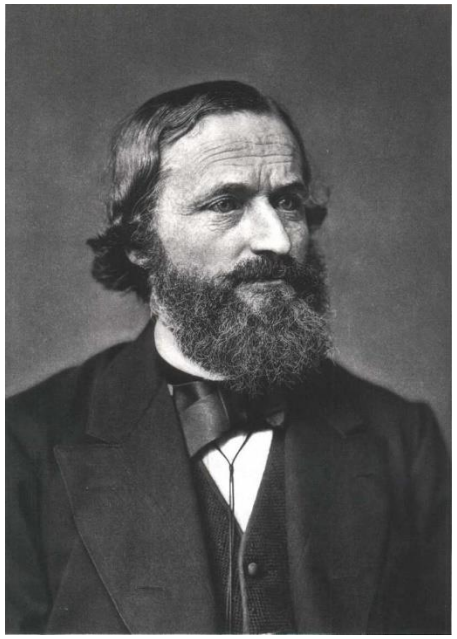
1849. (Léon Foucault) i 1855. (Ångström) – atomi u plamenu emitiraju iste valne duljine koje (hladne) pare apsorbiraju

Joseph von Fraunhofer
(1787.–1826.)

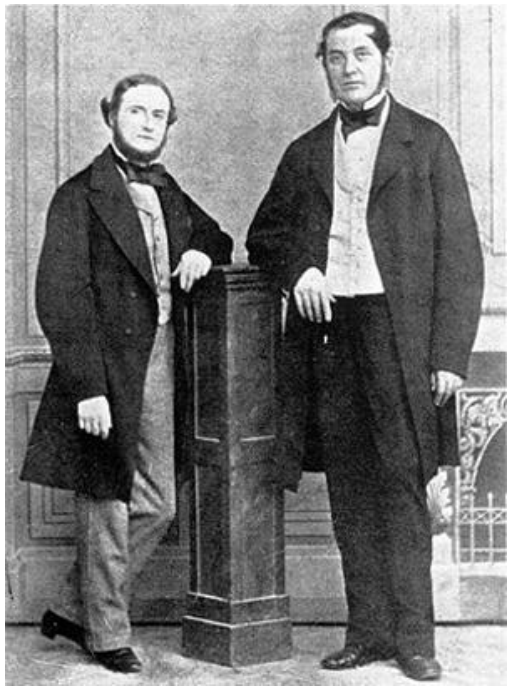


William Henry Fox **Talbot**
(1800.–1877.)

Anders Jonas Ångström
(1814.–1874.)

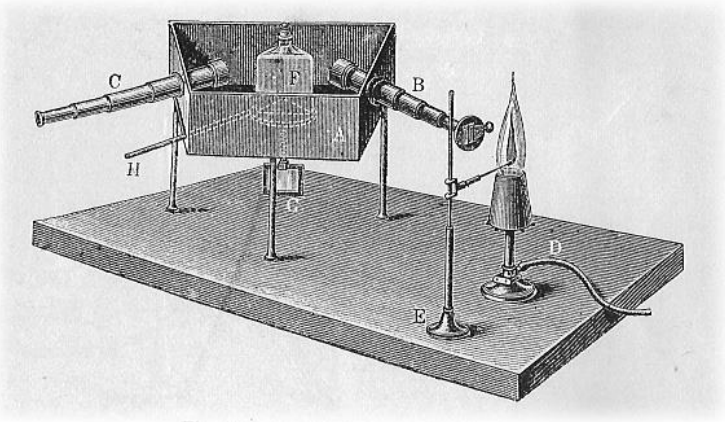


Gustav Robert **Kirchhoff**
(1824.–1887.)



Robert Wilhelm Eberhard **Bunsen** (1811.–1899.)

Peter Desaga
(1812. – iza 1879.)



Kirchhoff-Bunsenov spektroskop

Kirchhoffovi ‘zakoni spektroskopije’:

1. Vruća krutina, tekućina i plin pod visokim tlakom emitiraju kontinuirani spektar
2. Vrući plin pod niskim tlakom emitira linijski spektrar
3. Kada se kontinurirani spektar promatra kroz hladni plin niske gustoće (pod niskim tlakom) u njemu se pojavljuju apsorpcijske linije

Periodic table by era of discovery

V·T·E

Group → / ↓ Period	1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc		22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y		40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
				*	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
				**	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

Background color shows age of discovery:

Antiquity to Middle Ages	Middle Ages–1799	1800–1849	1850–1899	1900–1949	1950–1999	Since 2000
(12 elements) Antiquity to Middle Ages: unrecorded discoveries up into the Middle Ages	(22 elements) Discoveries during the age of enlightenment	(25 elements) Scientific and industrial revolutions	(24 elements) The age of classifying elements; application of spectrum analysis techniques: Boisbaudran, Bunsen, Crookes, Kirchhoff, and others "hunting emission line signatures"	(14 elements) Development of old quantum theory and quantum mechanics	(16 elements) Post Manhattan project; synthesis of atomic numbers 98 and above (colliders, bombardment techniques)	(5 elements) Recent synthesis

Sistematizacija elemenata - Döbereiner

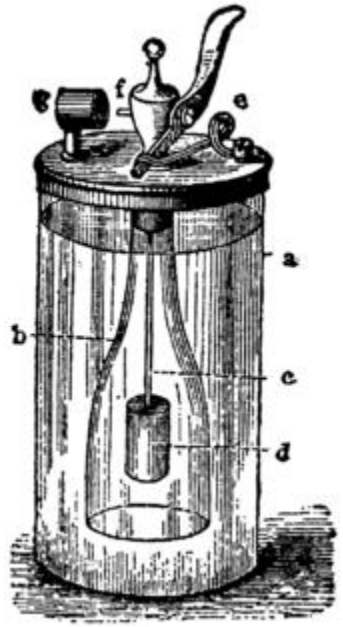
Johann Wolfgang Döbereiner
(1780.–1849.)

1817. – 1829. ‘**Zakon trijada**’:

Kemijski analogni elementi se slažu prema porastu pripadnih atomskih težina u dobro definirane skupine zvane ‘*trijade*’ u kojima je atomske težina srednjeg elementa u pravilu aritmetička sredina atomskih težina drugih dvaju elemenata u *trijadi*.

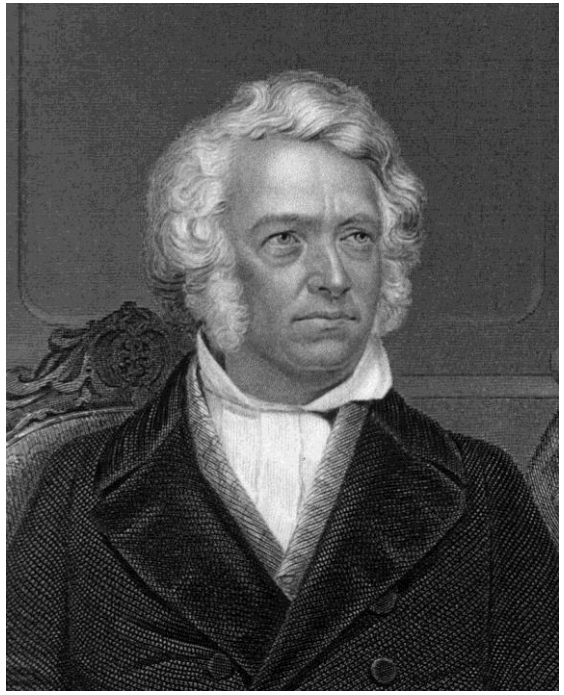
Trijade:

1. **Cl, Br, I**
2. **Ca,Sr, Ba**
3. **S, Se, Te**
4. **Li, Na, K**



Dobereinerova lampa (upaljač), 1823.

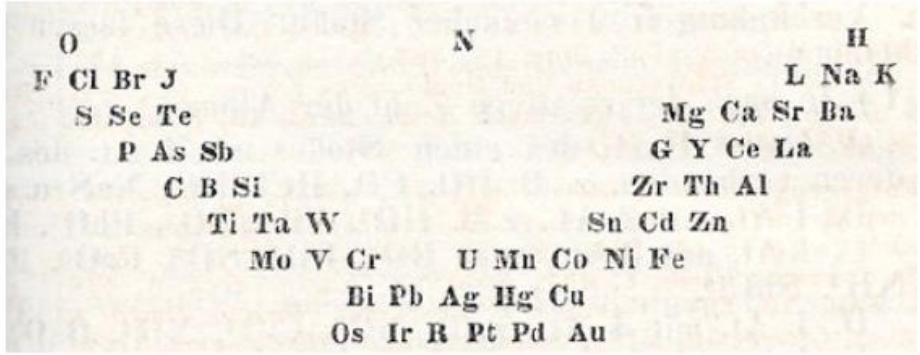
Sistematizacija elemenata – Gmelin

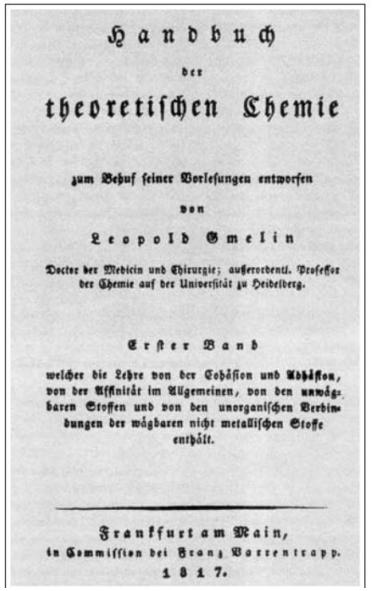


Leopold Gmelin
(1788.–1853.)

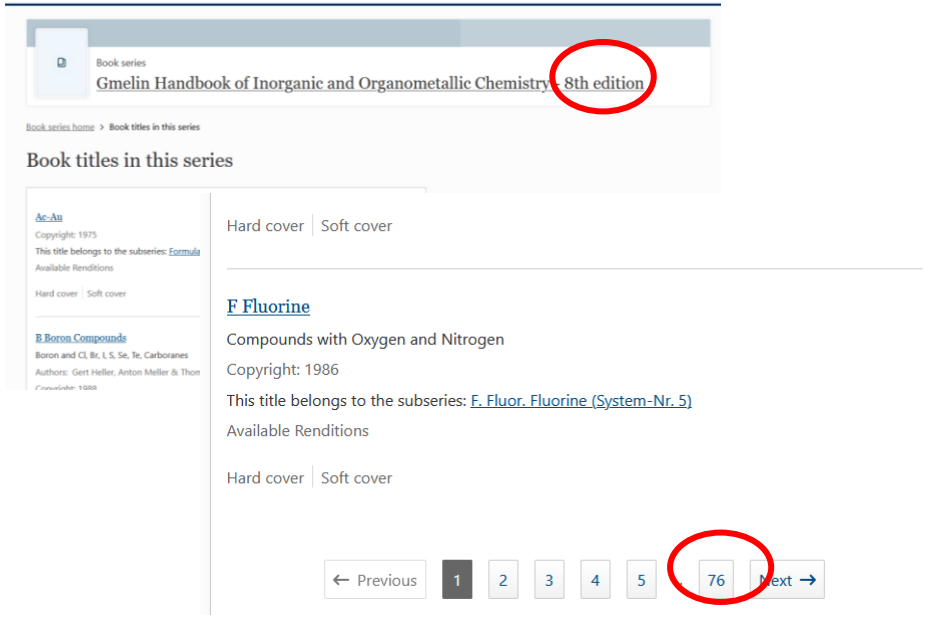
1843. *Körpernetze*

U 4. izdanju *Handbuch der Chemie*:
Tijade (i veće grupe) se slažu po valencijama (opadaju prema dolje) i elektronegativnosti (raste s lijeva na desno) u ‘mrežu’ oblika slova V


O N H
F Cl Br J L Na K
S Se Te Mg Ca Sr Ba
P As Sb G Y Ce La
C B Si Zr Th Al
Ti Ta W Sn Cd Zn
Mo V Cr U Mn Co Ni Fe
Bi Pb Ag Hg Cu
Os Ir R Pt Pd Au


Handbuch
der
theoretischen Chemie
zum Behuf seiner Vorlesungen entworfen
von
Leopold Gmelin
Doctor der Medicin und Chirurgie; außerordentl. Professor der Chemie auf der Universität zu Heidelberg.
Erster Band
welcher die Lehre von der Cohäsion und Adhäsion, von der Affinität im Allgemeinen, von den unwägbaren Stoffen und von den unorganischen Verbindungen der wägbaren nicht metallischen Stoffe enthält.
Frankfurt am Main,
in Commission bei Franz Varrentrapp.
1817.

L. Gmelin, *Handbuch der theoretischen Chemie* (1. izdanje, 1817.)

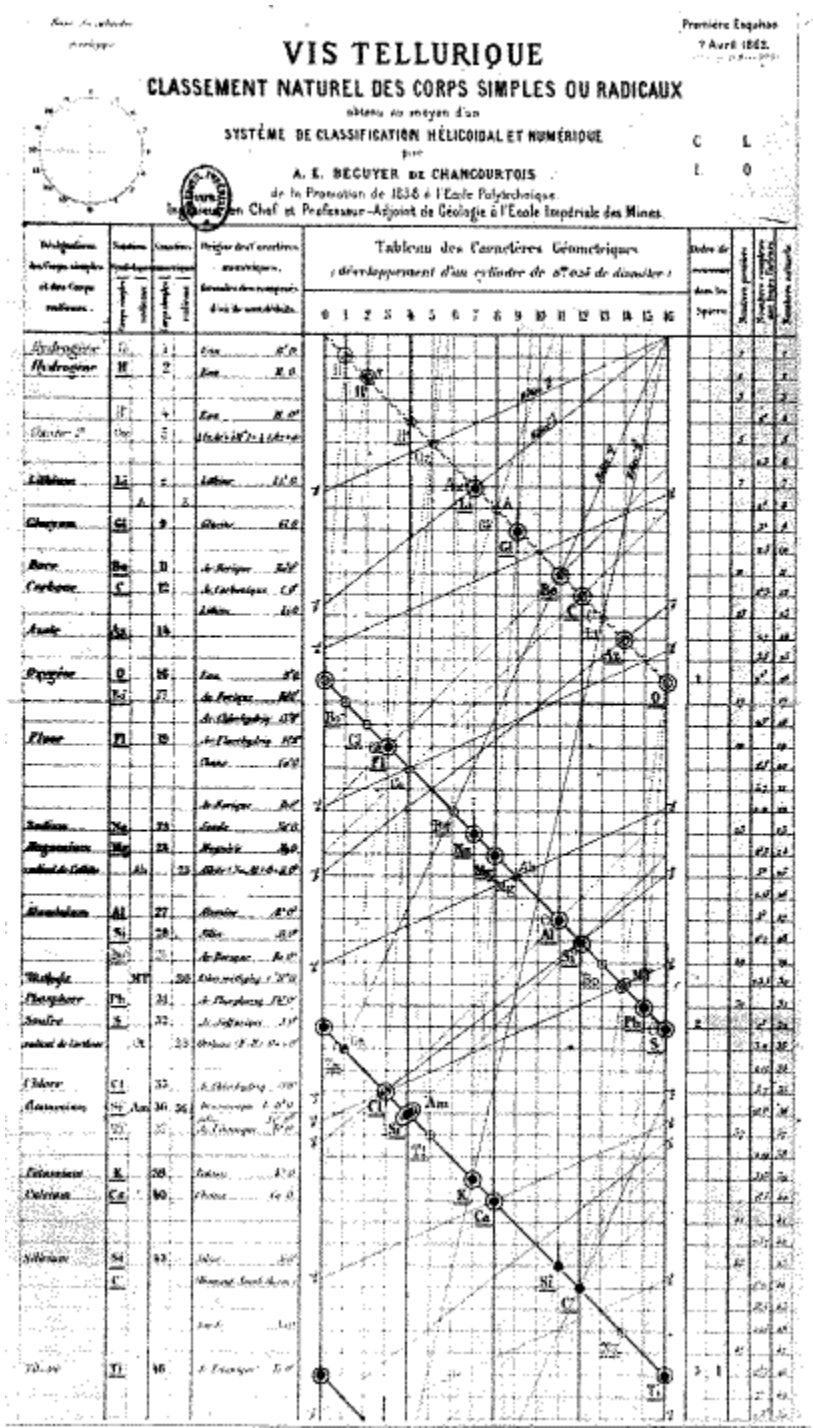


Sistematizacija elemenata – de Chancourtois

Alexandre-Émile Béguyer de Chancourtois (1820.–1886.)

1862. ‘**Telurijska zavojnica**‘

Svojstva elemenata poredinih po porastu atomske mase mijenjaju se periodično: mogu se posložiti u 3D dijagram tako da čine spiralu na cilindru – atomi sličnih svojstava padaju na istu vertikalu.



Sistematizacija elemenata – Odling

William Odling,
(1829.–1921.)

1864. „**On the proportional numbers of the elements**”

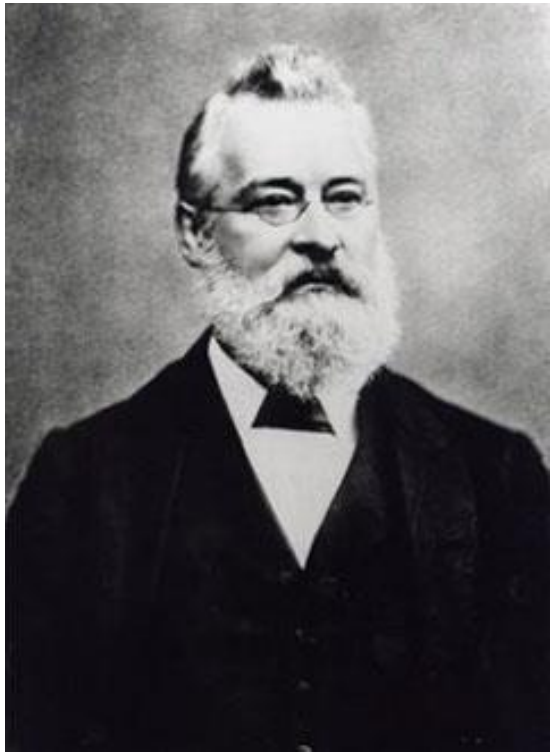
Upon arranging the atomic weights or proportional numbers of the sixty or so recognized elements in order of their several magnitudes, we observe a marked continuity in the resulting arithmetical series…. With what ease this purely arithmetical seriation may be made to accord with a horizontal arrangement of the elements according to their usually received groupings is shown in the following table, in the first three columns of which the numerical sequence is perfect, while in the other two the irregularities are but few and trivial.

			Ro 104	Pt 197
			Ru 104	Ir 197
			Pd 106·5	Os 199
H 1	„	„	Ag 108	Au 196·5
„	„	Zn 65	Cd 112	Hg 200
L 7	„	„	„	Tl 203
G 9	„	„	„	Pb 207
B 11	Al 27·5	„	U 120	„
C 12	Si 28	„	Sn 118	„
N 14	P 31	As 75	Sb 122	Bi 210
O 16	S 32	Se 79·5	Te 129	„
F 19	Cl 35·5	Br 80	I 127	„
Na 23	K 39	Rb 85	Cs 133	„
Mg 24	Ca 40	Sr 87·5	Ba 137	„
	Ti 50	Zr 89·5	Ta 138	Th 231·5
	„	Ce 92	„	
	Cr 52·5	Mo 96	V 137	
	Mn 55		W 184	
	Fe 56			
	Co 59			
	Ni 59			
	Cu 63·5			

Sistematizacija elemenata – Newlands

1865. '**Zakon oktava**':

Kada se elementi poslože po porastu atomske težine, između elemenata sličnih svojstava stoji po 7 (ili 14) drugih elemenata



John Alexander Reina **Newlands** (1837.–1898.)

It will also be seen that the numbers of analogous elements generally differ either by 7 or by some multiple of seven; in other words, members of the same group stand to each other in the same relation as the extremities of one or more octaves in music. Thus, in the nitrogen group, between nitrogen and phosphorus there are 7 elements; between phosphorus and arsenic, 14; between arsenic and antimony, 14; and lastly, between antimony and bismuth, 14 also.
This peculiar relationship I propose to provisionally term the "Law of Octaves."

J. A. R. Newlands, *"On the Law of Octaves". Chemical News.* **12**: (1865) 83.

No.	No.	No.	No.	No.	No.	No.	No.
H 1	F 8	Cl 15	Co & Ni 22	Br 29	Pd 36	I 42	Pt & Ir 50
Li 2	Na 9	K 16	Cu 23	Rb 30	Ag 37	Cs 44	Os 51
G 3	Mg 10	Ca 17	Zn 24	Sr 31	Cd 38	Ba & V 45	Hg 52
Bo 4	Al 11	Cr 19	Y 25	Ce & La 33	U 40	Ta 46	Tl 53
C 5	Si 12	Ti 18	In 26	Zr 32	Sn 39	W 47	Pb 54
N 6	P 13	Mn 20	As 27	Di & Mo 34	Sb 41	Nb 48	Bi 55
O 7	S 14	Fe 21	Se 28	Ro & Ru 35	Te 43	Au 49	Th 56

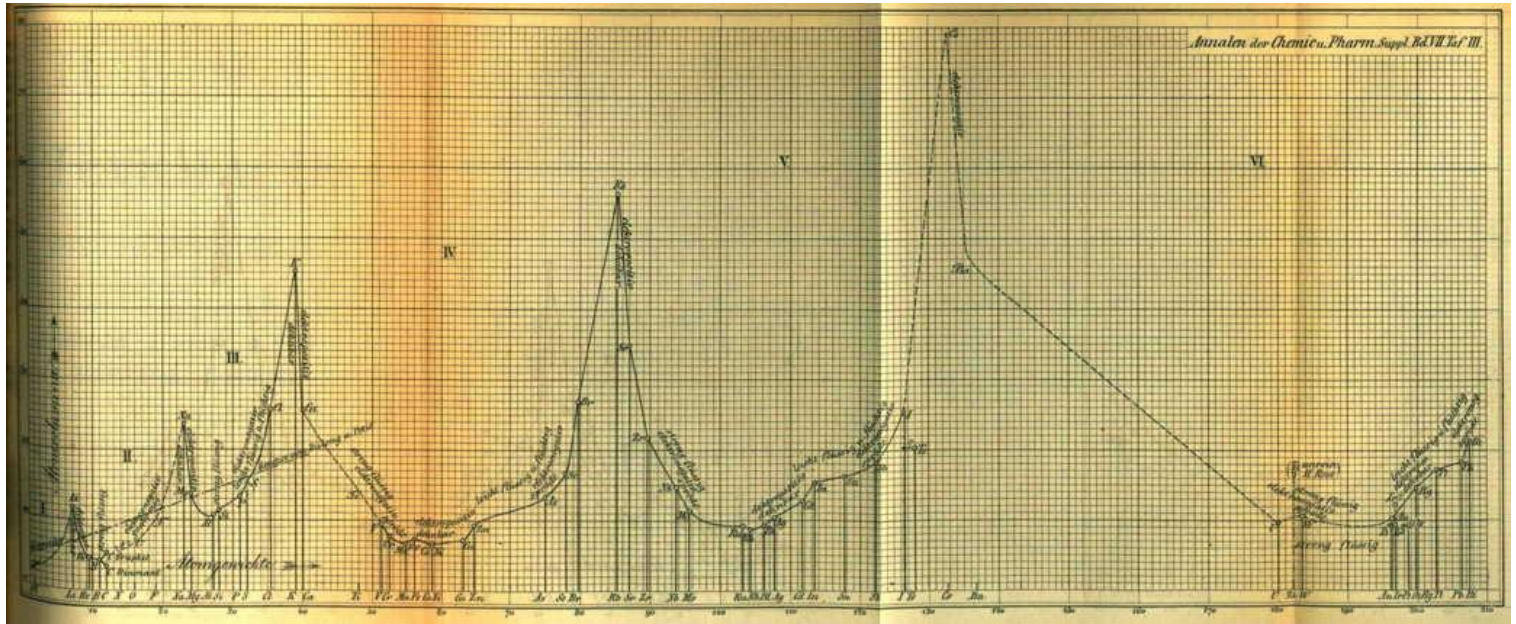
Sistematizacija elemenata – (Lothar) Meyer

Julius **Lothar Meyer**
(1830.–1895.)

1864. Klasifikacija elemenata prema valencijama
1868. Djelomična tablica periodnog sustava
1869./1870. Potpuna tablica
1870. Ovisnost atomskog volumena o atomskoj težini (*krivulja Lothara Meyera*)

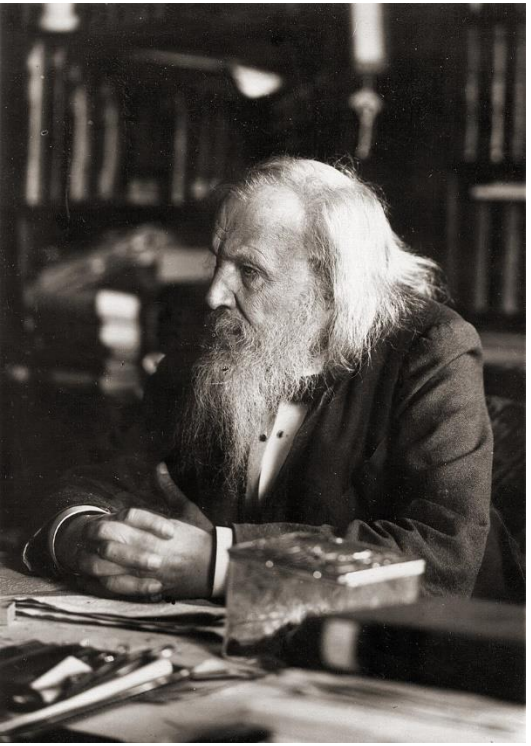
	4 werthig	3 werthig	2 werthig	1 werthig	1 werthig	2 werthig
	—	—	—	—	Li = 7,03	(Be = 9,3?)
Differenz =	—	—	—	—	16,02	(14,7)
	C = 12,0	N = 14,04	O = 16,00	Fl = 19,0	Na = 23,05	Mg = 24,0
Differenz =	16,5	16,96	16,07	16,46	16,08	16,0
	Si = 28,5	P = 31,0	S = 32,07	Cl = 35,46	K = 39,13	Ca = 40,0
Differenz =	$\frac{89,1}{2}$ = 44,55	44,0	46,7	44,51	46,3	47,6
	—	As = 75,0	Se = 78,8	Br = 79,97	Rb = 85,4	Sr = 87,6
Differenz =	$\frac{89,1}{2}$ = 44,55	45,6]	49,5	46,8	47,6	49,5
	Sn = 117,6	Sb = 120,6	Te = 128,3	J = 126,8	Cs = 133,0	Ba = 137,1
Differenz =	89,4 = 2.44,7	87,4 = 2.43,7	—	—	(71 = 2.35,5)	—
	Pb = 207,0	Bi = 208,0	—	—	(Tl = 204?)	—

L. Meyer, ***Die modernen Theorien der Chemie***, 1864.



krivulja Lothara Meyera, 1870.

Sistematizacija elemenata – Mendjeljejev



Dmitri Ivanovič Mendjeljeev
(Дмитрий Иванович Менделеев 1834.–1907.)

6. III. 1869. – zakon periodičnosti

1. Elementi poredani po porastu atomske težine pokazuju periodičnost svojstava
2. Elementi sličnih svojstava ili imaju slične atomske težine (Pt, Ir, Os) ili im se atomske težine pravilno povećavaju (K, Rb, Cs)
3. Raspored elemenata u grupama po atomskoj težini odgovara valencijama kao i kemijskim svojstvima (Li, Be, B, C, N, O, F)
4. Najrasprostranjeniji elementi su oni malih atomskih težina
5. Iznos atomske težine određuje svojstva elementa kao što iznos molekulske težine određuje svojstva molekule
6. Treba očekivati otkrića mnogih novih elemenata, npr. dva elementa, analogna aluminiju i siliciju, atomskih težina između 65 i 75
7. Atomska težina nekih elemenata se može ispraviti temeljem atomskih težina susjednih. Tako telurijeva mora biti između 123 i 128, a ne može biti 128.
8. Pojedine karakteristike elemenata mogu se predvidjeti temeljem njihovih atomskih težina.

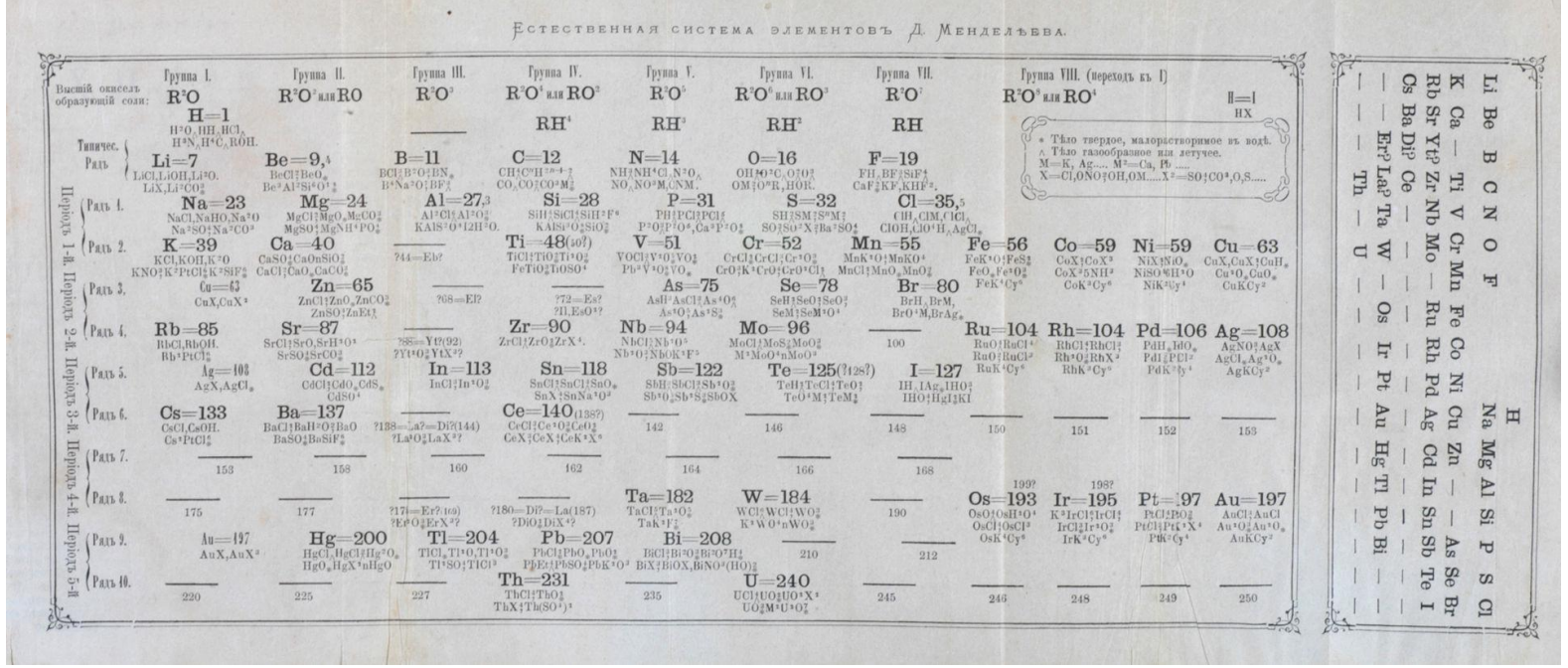
ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

			Ti = 50	Zr = 90	? = 180.
			V = 51	Nb = 94	Ta = 182.
			Cr = 52	Mo = 96	W = 186.
			Mn = 55	Rh = 104,4	Pt = 197,1.
			Fe = 56	Ru = 104,4	Ir = 198.
			Ni = Co = 59	Pl = 106,6	O = 199.
H = 1			Cu = 63,4	Ag = 108	Hg = 200.
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,1	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,6	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204.
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207.
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,6	Th = 118?		

Д. Менделѣевъ

1869.



1870.

Reihen	Gruppo I. — R'O	Gruppo II. — RO	Gruppo III. — R'O³	Gruppo IV. RH⁴ RO²	Gruppo V. RH³ R'O⁵	Gruppo VI. RH² RO³	Gruppo VII. RH R'O⁷	Gruppo VIII. — RO⁴
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

1871.

Potvrde – nedostajući elementi

Paul-Émile (François) Lecoq de Boisbaudran (1838.–1912.)

1875. *eka-aluminij* = Ga

Lars Fredrik Nilson
(1840.–1899.)

1879. *eka-Bor* = Sc

Clemens Alexander Winkler
(1838.–1904.)

1886. *eka-silicij* = Ge

Proširenje – plemeniti plinovi

Sir **William Ramsay**
(1852.–1916.)

John William Strutt,
3. barun **Rayleigh**
(1842.–1919.)

[1868., Sir Joseph Norman Lockyer, *helium*]

1894. – Ar, [He]

1898. – Ne, Kr, Xe

[1898., Friedrich Ernst Dorn, *radijeva emanacija*]

1904. [Rn]

1900. (Ramsay & Mendjeljejev – grupa 0)

Stanje početkom XX. stoljeća

...																									...	...
H																									...	He
Li																						Be	B	C	N	O	F	Ne
Na																						Mg	Al	Si	P	S	Cl	A
K	Ca															Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr															Y	Zr	Nb	Mo	...	Ru	Rh	Pd	Ag	Cd	Jn	Sn	Sb	Te	J	Xn
Cs	Ba	La	Ce	Nd	Pr	...	...	Sa	Eu	Gd	Tb	Ho	Er	Tu	Y	...	...	Ta	W	...	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	...	...	...
...	Ra	Laα	Th	...	...	...	...	...	U	...	...	...	...	Ac	...	...	...	...	...	...	...	...	...	...	...	...	Pbα	Biα	Teα	...	...

(A. Werner, 1905.)